DEVELOPMENT OF GRAPHICAL USER INTERFACE (GUI) FOR BEARING FAULT DETECTION

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ABSTRACT

Rolling element bearing has vast domestic and the vital parts in any rotating machinery. Appropriate function of these appliances depends on the smooth operation of the bearings. Failure of this particular part can affect the machinery performance and in time will cause major failure to the machinery. Result of various studies shows that bearing problems account for over 40% of all machine failures. Due to the crucial problem, online monitoring has become an alternative in preventive maintenance. The objective of this project is to develop software with signal processing tools to detect defect features in mechanical signal of the bearing. Five set of bearing were tested with one of them remains in good condition while the other four has its own type of defects. The data for good bearing were used as baseline data to compare with the defected ones. The data consist with three different speed rotation which are 287, 1466, and 2664 rpm. Then analyzed by using Continuous Wavelet Transform (CWT). From there, it is further analyse using wavelet coefficient for each level of decomposition from CWT method. From the result generated, Fast Fourier Transform (FFT) and wavelet coefficient plays an important role in supporting result analyzed by using CWT that will be used on Graphical User Interface (GUI) software in MATLAB. A system or data with low wavelet coefficient compare to the good condition wavelet coefficient will clearly state as in good condition bearing while the defect features still may be recovered by calculating the wavelet coefficient for each level of decomposition in CWT method. If the wavelet coefficient of data is higher than the good bearing, it proves that the defect occurred on that bearing. The GUI will display the result of the CWT process by displaying condition of the bearing either in good condition or not. Finally, the CWT method also proves to be an effective method for online condition monitoring tool with GUI software. Future research should be detecting type of the defect features based on statistical tool.

ABSTRAK

Galas mempunyai aplikasi domestik dan penting terdapat di dalam jentera berputar. Fungsi peralatan ini bergantung kepada kelancaran galas sendiri. Kegagalan bahagian ini tertentu boleh menjejaskan prestasi jentera dan dalam masa yang sama, ia akan menyebabkan kegagalan utama kepada jentera. Hasil daripada pelbagai kajian, ia menunjukkan bahawa masalah galas menyumbang lebih 40% daripada kebanyakkan kegagalan mesin. Oleh kerana masalah yang serius, pemantauan dalam talian telah menjadi alternatif bagi penyelenggaraan servis pencegahan mesin. Objektif projek ini adalah untuk membina perisian dengan alat pemprosesan isyarat untuk mengesan ciri-ciri kecacatan dalam isyarat mekanikal pada galas. Lima set galas telah diuji dengan salah satu daripada galas tersebut berada dalam keadaan yang baik, manakala empat yang lain mempunyai berlainan kecacatan. Data untuk galas yang baik telah digunakan sebagai penanda aras untuk dibandingkan dengan data-data galas yang rosak. Data tersebut terdiri daripada tiga kelajuan putaran mesin yang berbeza iaitu 287, 1466, dan 2664 putaran per minit. Data ini akan dianalisis dengan menggunakan kaedah *Continous Wavelet Transform (CWT).* Kemudian, data akan dianalisis menggunakan *Wavelet Coefficient* untuk setiap peringkat penguraian di dalam kaedah CWT. Dari keputussan yang diperolehi, *Fast Fourier Transform (FFT)* dan *wavelet coefficient* memainkan peranan penting dalam analisa CWT dimana keputusan itu akan digunakan pada perisian antara muka grafik pengguna di dalam perisian *MATLAB*. Setiap data yang mempunyai *wavelet coefficient* yang rendah berbanding dengan *wavelet coefficient* galas rujukan, galas tersebut berada dalam keadaan yang baik, manakala kecacatan masih boleh dikenalpasti dengan mengira *wavelet coefficient* bagi setiap peringkat penguraian yang digunakan dalam kaedah CWT. Jika *wavelet coefficient* data adalah lebih tinggi daripada *wavelet coefficient* galas yang baik, ia membuktikan bahawa kecacatan telah berlaku pada galas tersebut. GUI akan memaparkan hasil daripada proses CWT dengan menyatakan bahawa keadaan galas sama ada galas tersebut berada dalam keadaan baik atau tidak. Kesimpulannya, kaedah CWT membuktikan bahawa ia merupakan salah satu kaedah yang berkesan bagi mengenalpasti kehadiran kecacatan galas dalam talian dengan menggunakan alat pemantauan daripada perisian GUI. Kajian masa depan boleh dilaksanakan dengan mengesan jenis-jenis kecacatan pada galas tersebut.

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LIST OF SYMBOL

ω_s	Shaft rotation frequency
α	Contact angle
$\psi(t)$	Mother wavelet

LIST OF ABBREVIATIONS

ASiVR	Advance Structural Integrity & Vibration Research
CUI	Character User Interface
CWT	Continuous Wavelet Transform
DWT	Discrete Wavelet Transform
FFT	Fast Fourier Transform
GUI	Graphical User Interface
RPM	Revolutions per minute
STFT	Short Time Fourier Transform
WT	Wavelet Transform
WYSIWYG	What you see is what you get

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

This chapter discusses the about the project background, problem statement, the objectives, scopes of project, project flow and project Gantt chart. Besides that, it also consists with the thesis overview for this project.

1.1 PROJECT BACKGROUND

Ball bearing failures can be caused by several factors, such as incorrect design or installation, acid corrosion, poor lubrication and plastic deformation (R. Rubini and U. Meneghetti 2000). Detecting or even preventing failures in complex machines usually benefits in terms of economy and security. However, defects can occur due to the great number of critical processes where bearings are employed. The precocious diagnosis of possible faults constitutes an important activity to prevent more serious damages.

Therefore, this type of fault must be detected as soon as possible to avoid fatal breakdowns of machines that may lead to loss of production. Bearing defects may be categorized as “distributed” or “local” (N. Tandon, A. Choudhury 1999). Distributed defects include surface roughness, waviness, misaligned races and off-size rolling elements. Localized defects include cracks, pits and spalls on the rolling surfaces. The faulty bearing in the rotating parts or engineering components will excite the vibration signal with different behavior or structure. Therefore, the advance signal analysis is required to evaluate the vibration signatures from different type of bearing defect.

There are many condition monitoring methods used for detection and diagnosis of rolling element bearing defects such as wear debris analysis, temperature measurement, vibration measurement, and acoustic emission. Several techniques have been applied to measure the vibration and acoustic responses from defective bearings such as vibration measurements in time and frequency domains, the shock pulse method, sound pressure and sound intensity techniques and the acoustic emission method. Based on research mostly in last two decades, there are a lot work research on the detection and diagnosis of bearing defects by vibration and acoustic methods. Among these, vibration measurements are the most widely used (N. Tandon, A. Choudhury 1999).

1.2 PROBLEM STATEMENT

The growing demand for high performance, efficiency, safety and reliability and increasing complexity of the technical processes has been of great interest in the development of fault detection methods (C. Angeli 2004). The early detection of faulty may help to avoid system breakdowns and product deterioration. Fault detection algorithms and their applications to a wide range of industrial processes has been the subject of intensive research over the past two decades. Existing methods for the fault detection have widely focused on the steady-state operations and are not directly applicable during the transitions. Recent results of studies show that more than 40% of induction motor failures are related to bearing (Tandon and Choudhury 1999). These data acquisition is a type of non-destructive which is does not required the user to dismantle the bearing from the machine in order to check its condition as it may be presented through online monitoring. In industries, high skill required from person in charge to know either the bearing is in good condition or not with or without dismantle the bearing from the machine.

1.3 OBJECTIVES

The objectives of this project are:

a) To develop software with signal processing tools to detect defect features in mechanical signal.
b) To study a method to detect defect features in time-frequency domain for vibration signal
c) To determine specific indicator in time and frequency domain to detect defect features

1.4 PROJECT SCOPES

In order to reach the project's objectives, the following scopes are identified:

a) Test four of bearing defect and they are inner race defect, outer race defect, contaminated defect, and corroded ball.
b) Make a good condition bearing as the reference/datum.
c) Graphical User Interface (GUI) analysis developed by using MATLAB
d) Analysis method by using Continuous Wavelet Transform (CWT) method

1.5 PROJECT FLOW CHART

In conducting a project, well arrangement of works and task is important to keep the momentum of this study. Figure 1.1 shows the flow chart for this project.

The process started with identify the problem statement especially problem face in industry, the objectives and scopes of this project. After that, the problem identification will follow the flow and continue with the finding the related journal or literature review about this title. It will help to gain the knowledge and also help to discuss about this project.

The next step will be continued in Final Year Project 2 (FYP2) which is the data will be analysed by using Continuous Wavelet Transform (CWT) method. The data had been acquired from previous study. At this step, the coding of the CWT method will generate in MATLAB software. After the result of the analysis had validation to detect the defect occurred in the bearing, it will be continued by developing the Graphical User Interface (GUI) in the MATLAB. Then, the result of the GUI will discuss and conclude the project.

Figure 1.2 shows the Gantt chart of this project which is for final year project 1 and 2. From the chart, there is some of the task is not follow the planning schedule. It is because there are some problem occurred when performing the task such as need to change the method because of validations the data with the result and also lack of knowledge of the software.

Basically, the project still moves on with the flow of the planning and had done within the time given.

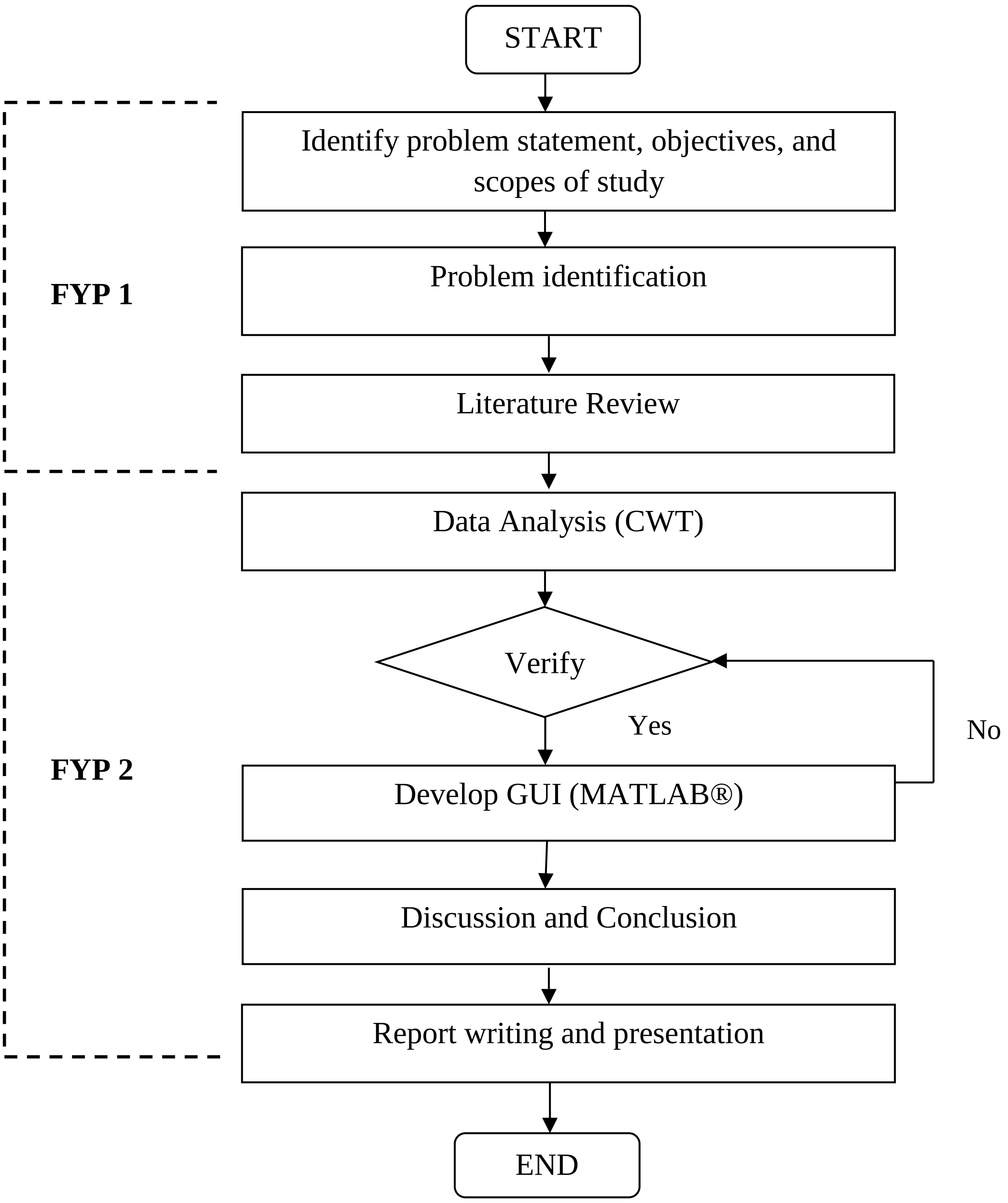
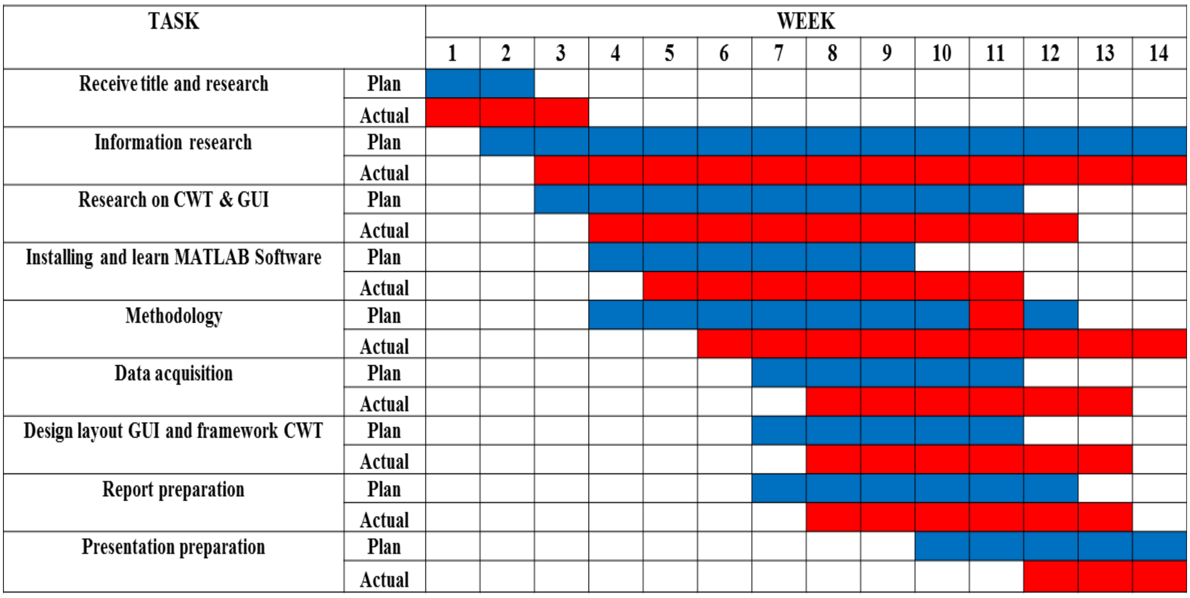


Figure 1.1: Project's Flow Chart

FYP 1



FYP 1

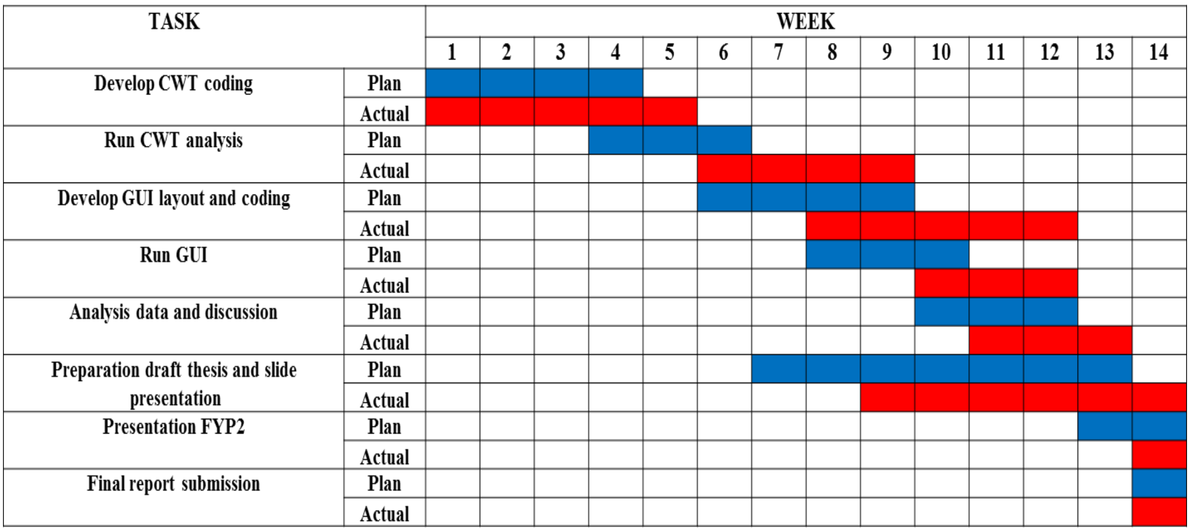


Figure 1.1: Project's Gantt chart

1.6 THESIS OVERVIEW

Chapter 1 introduces the background of the study. It is continue with simple discussion about ball bearing defect, problem statement which related to the study, the objectives, and scope of the study, the flow chart and Gantt chart for this project and the overview of the thesis.

Chapter 2 presents the information of bearing, types of bearing defect, and signal processing. This chapter also will discuss about Continuous Wavelet Analysis (CWT) and Graphical User Interface (GUI). It also includes the bearing fault detection and condition monitoring method.

Chapter 3 includes the comprising methodology of this project. This chapter also will discuss about data acquisition, data processing analysis by using CWT method. This chapter will enclosed with the design layout of GUI and develop it by using MATLAB®.

Chapter 4 will present the result of the tabulation result or data and further discusses about the outcome of the analysis. It will show more detail about the development of GUI for bearing fault detection.

This study will enclosed by chapter 5 with the conclusion for this project and recommendation for future research.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter discuss the literatures review related to bearing fault detection, Graphical User Interface (GUI) and Continuous Wavelet Transform (CWT). This title requires an amount of good understanding on the knowledge and executes a research is necessary to obtain the information are essentially valuable and suitable to assist in the construction of this project. In this chapter, it also explain discuss types of bearing and types of bearing defects, signal analysis, CWT, GUI, bearing fault detection and condition monitoring method.

2.1 BEARING

Bearing is a machine element that constrains relative motion between moving parts to only the desired motion. This mechanical device is typically in between linear and rotational movement (Richard H. 1997). There are many types of bearing often used in machinery field and each of them had their own purpose itself. Inventions of bearings such as roller bearing, hydrodynamics, hydrostatics and magnetic bearing, fluid bearing, and also flexure bearing made it possible to operate a shaft induced in load and high speed while jewel bearing and plain bearing just required in load and low speed (Purtell, John 2000).

Roller bearing as shown in Figure 2.1 is a bearing which carries a load by placing round elements between two bearing rings. It is very easy to use in various equipment by its rolling facility It is widely used because that are advantages of a good trade-off between cost, size, weight, carrying capacity, durability, accuracy, friction, and etc. (Harris, Tedric A. 2000).

Figure 2.1: Roller bearing

Source: FAG 2006

2.1.1 Types of Bearing Defects

Bearings are among the most important components in the vast majority of machines and exacting demands are made upon their carrying capacity and reliability. Unfortunately it sometimes happens that a bearing does not attain its calculated rating life. Each of the different causes of bearing failure produces its own characteristic damage known as primary and secondary damage. Primary damage consists of wear indentations, smearing, surface distress, corrosion, and electric current damage. Secondary damage includes flaking and cracks.

Table 2.1 shows the different types of bearing damage, its appearance, and causes of this damage. Each type of defect has own characteristic and also appearance. Some of the defect has come with the same causes but the differentiation between them is the appearance defect itself.

Table 2.1: Types of bearing damage, appearance, and possible causes.

Types of damage	Appearance	Causes
Wear	• Small indentations around the raceway and rolling element • Grease discolored green • Wear on inner/outer rings	• Lack of cleanliness during mounting • Ineffective seals • Sliding abrasion, bearing of insufficient hardness, contamination by foreign matter shortage of lubricant, improper lubrication
Indentations	• Indentations in the raceways of both rings with spacing equal to the distance between the rolling elements • Small indentations distributed around the raceways of both rings and in the rolling elements.	• Mounting pressure applied to the wrong ring • Excessively hard drive-up on tapered seating • Ingress of foreign particles into the bearing.
Cracks	• Bearing ring has cracked right through and has lost its grip on the shaft.	• Excessive drive-up on a tapered seating or sleeve.
Surface Distress	• Small, shallow craters with crystalline fracture surfaces	• Inadequate or improper lubrication.
Flaking	• Heavily marked path pattern in raceways of both rings. • Usually in the most heavily loaded zone. • Heavily marked path pattern at two diametrically opposed sections of either bearing ring.	• Preloading on account of fits being too tight. • Excessive drive-up on a tapered seating • Oval shaft or oval housing seating.
Corrosion	• Greyish black streaks across the raceways • Raceway path pattern heavily marked at corresponding positions.	• Presence of water, moisture • Shaft or housing seating with errors of form.

Table 2.1: Continued

Types of damage	Appearance	Causes
Smearing	• Scored and discolored roller ends and flange faces. • Scored and discolored areas at the start of the load zone in raceways and on the surface of the rollers. • Scored and discolored ring bore or outside surface or faces. • Scored and discolored ring bore or outside surface or faces.	• Sliding under heavy axial loading and with inadequate lubrication. • Roller acceleration on entry into the loaded zone. • Ring rotation relative to shaft or housing. • Ring rotation relative to shaft or housing.
Electric Current	• Dark brown/greyish black fluting (corrugation) or craters in raceways and rollers. • Localized burns in raceways and on rolling elements	• Passage of electric current through rotating bearing. • Passage of electric current through non-rotating bearing.

Source: SKF Handbook 1994

There are four common categories of bearing fault which are outer race, inner race, ball and cages. Bearing defect usually occur on three area of the bearing which are the outer race, inner race and the ball bearing itself (Martin and Honarvar 1994). Usually this failure occurred according by either overloading, over speeding or also starving of lubrication.

Figure 2.2 show the outer race defect of the tested bearing. The outer race is the retainer or holder for all bearing assembly whereas the outer most surfaces will be contact with the baring holder mechanism in a shaft assembly or any machinery assembly. Figure 2.3 shows the exploded view of bearing assembly

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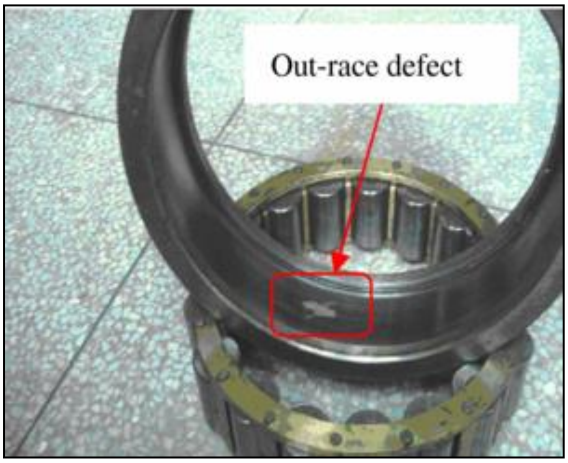

Figure 2.2: The outer race defect of the tested bearing

Source: Measurement and Technology 2012

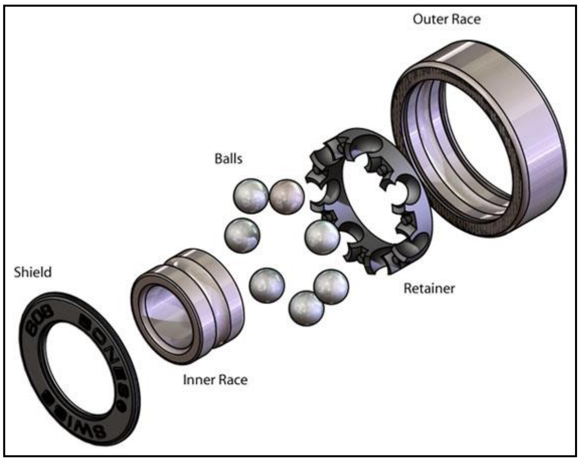

Figure 2.3: Exploded view of bearing assembly

Source: Bones Baring 2011

The other part retainer of a ball bearing assembly also includes the inner race but it only for the inner part. The inner also is the most surfaces in direct contact with a shaft in a pump or machinery assembly.

The ball is one of the most important parts in a ball bearing. It acts as less friction characteristic in a high speed rotation usage contributed most form. On these two areas of outer and inner race, there is also the defect that usually found on this area such as point defect, line defect and rough defect.

2.2 SIGNAL ANALYSIS

Signal processing is an area of engineering, electrical and applied mathematics that deals with operations on or analysis of signals, measurements of time-varying or spatially varying physical quantities. Signals of interest include sound, images, and sensor data, like biological data such as is electrocardiograms, control system signals, telecommunication transmission signals, and etc. (Schafer, Ronald W. 1975).

2.2.1 Frequency Domain Analysis

Frequency domain is a method used to analyze data. This refers to analyzing a mathematical function or a signal with respect to the frequency. Frequency domain analysis is widely used in fields such as control systems engineering, electronics and statistics. Frequency domain analysis is mostly used to signals or functions that are periodic over time

The advent of modern Fast Fourier Transform (FFT) analyzers to obtain narrowband spectra became easier and more efficient. Both low and high frequency ranges of the vibration signal or spectrum are of interest in assessing the condition of the bearing (Tandon and Choudhury 1999).

Each bearing elements has their own characteristics rotational frequency. There’s an increase in vibration energy at the element’s rotational frequency whenever there is a defect on a particular bearing. Theses characteristic defect frequencies can be calculated from kinematic considerations. For a bearing with a stationary outer race, these frequencies are given by the following expressions: